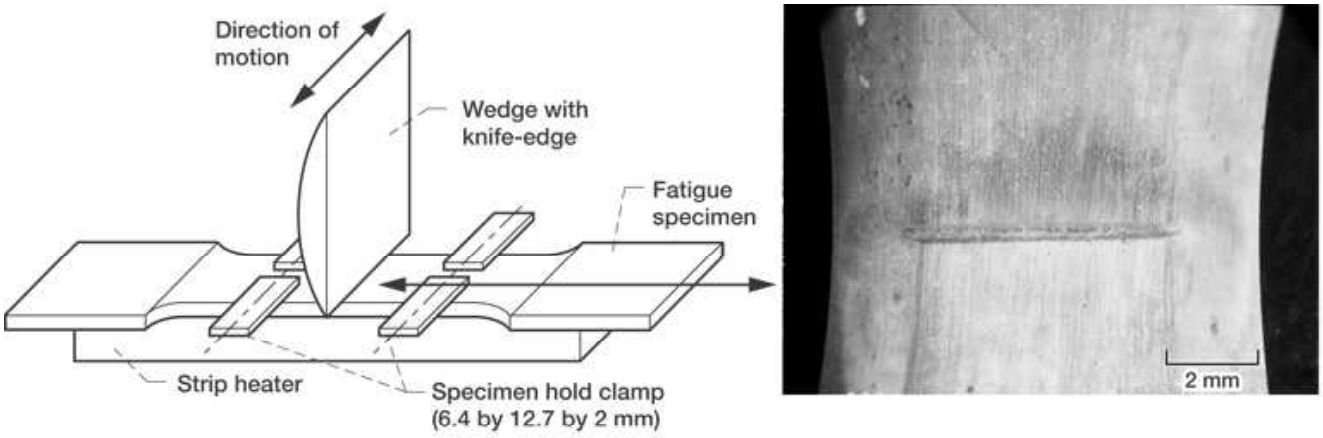
Fretting Fatigue of Gamma TiAl Studied

Gamma titanium-aluminum alloy (γ-TiAl) is an attractive new material for aerospace applications because of its low density and high specific strength in comparison to currently used titanium and nickel-base alloys. Potential applications for this material are compressor and low-pressure turbine blades. These blades are fitted into either the compressor or turbine disks via a dovetail connection. The dovetail region experiences a complex stress state due to the alternating centrifugal force and the natural high-frequency vibration of the blade. Because of the dovetail configuration and the complex stress state, fretting is often a problem in this area. Furthermore, the local stress state becomes more complex when the influence of the metal-metal contact and the edge of the contact is evaluated. Titanium and titanium-based alloys in the clean state exhibit strong adhesive bonds when in contact with themselves and other materials (refs. 1 and 2). This adhesion causes heavy surface damage and high friction in practical cases. Although the wear produced by fretting may be mild, the reduction in fatigue life can be substantial. Thus, there is the potential for fretting problems with these TiAl applications. Since TiAl is an emerging material, there has been limited information about its fretting behavior.



Left: Fretting setup. Right: Wear pattern on TiAl specimen gauge.
Long description of figure 1 Contact of a fretting wedge containing a knife-edge with a fatigue sample. The wedge is vibrated in a direction perpendicular to the longitudinal axis of the sample and at midgauge. This produces a slight groove in the gauge of the sample from edge to edge.

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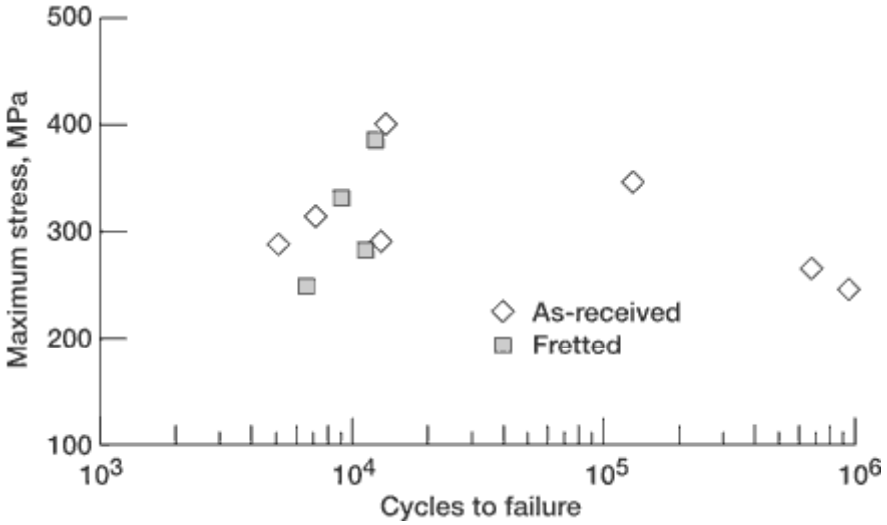
This study at the NASA Glenn Research Center provides preliminary information about the resistance of TiAl to fretting. The wear mechanisms in Ti-48Al-2Cr-2Nb were investigated in an earlier study (ref. 3). This investigation has been supplemented to include the influence of fretting on fatigue strength (ref. 4). Ti-48Al-2Cr-2Nb fatigue samples were fretted using wear pads of Inconel 718, a common disk material. One pad was rectangular with a flat wear surface. The second pad was wedgelike with a knife edge. The specimen was heated to various temperatures, and the contact pads were brought into

contact against the sample (see the sketch). The pads were oscillated against the samples with amplitudes of up to 90 μm and loads up to 450 N. Typical wear patterns are shown on the gauge of the fatigue sample in the photomicrograph. The samples were subsequently fatigue tested at a temperature of 650 °C, a frequency of 80 Hz, and a load ratio of 0.05. A step test method was employed using a block size of 10^6 cycles and a step size of 14 MPa.



Fatigue test results of fretted and unfretted samples.

Long description of figure 1 Fatigue strengths are equivalent for both fretted and unfretted samples. The average fatigue strength is 300 MPa and is relatively constant up to one million cycles to failure

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The results were somewhat unexpected: the fretted samples had lives equivalent to those of the unfretted samples (see the graph). This is easily explained since none of the fretted samples failed at the fret, but elsewhere in the gauge. Metallographic cross sections revealed slight impressions approximately 3 μm deep in the gauge of the fatigue specimen from the fretting process. However, no subsurface cracking was observed. Thus, the damage from the fretting process was not very severe. These results suggest that TiAl has good fretting resistance. In fact, with reciprocating pin-on-flat tests, TiAl had much better wear resistance than Ti-6Al-4V (ref. 3), which is a typical compressor blade material. Although only preliminary, the results suggest that TiAl has sufficient fretting resistance to withstand the wear in dovetail applications.

References

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